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☐ 2. 6130098 . 26 Sep 97; 10 Oct 00. Moving microdroplets. Handique; Kalyan, et al. 436/180; 366/DIG.2 422/100 422/102 422/56 422/58 422/81 422/82 436/52 436/53. G01N001/10 G01N001/18.

☑ 3. 6127125 . 08 Mar 99; 03 Oct 00. Sample application method and device. Yurino; Noriko, et al. 435/6; 435/810 436/501 536/23.1 536/25.3. C12Q001/68.

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L10	PCR near5 mineral oil near5 cover$3	14	L10
L9	L8 and cover$3	46	L9
L8	PCR near5 mineral oil	67	L8
L7	PCR near5 mineal oil	0	L7
L6	L5 and oil	0	L6
L5	L4 and humid	0	L5
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L2	L1 and mov$3 and PCR and temperature	1	L2
L1	5716825.pn.	2	L1

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L12: Entry 1 of 5 File: USPT Aug 7, 2001

DOCUMENT-IDENTIFIER: US 6271021 B1
TITLE: Microscale devices and reactions in microscale devices

Abstract Text (1):
The movement and mixing of microdroplets through microchannels is described employing silicon-based microscale devices, comprising microdroplet transport channels, reaction regions, electrophoresis modules, and radiation detectors. The discrete droplets are differentially heated and propelled through etched channels. Electronic components are fabricated on the same substrate material, allowing sensors and controlling circuitry to be incorporated in the same device.

Brief Summary Text (2):
The present invention relates to microfabrication of microscale devices and reactions in microscale devices, and in particular, movement of biological samples in microdroplets through microchannels to initiate biological reactions.

Brief Summary Text (17):
The present invention relates to microfabrication of microscale devices and reactions in microscale devices, and in particular, movement of biological samples in microdroplets through microchannels to initiate biological reactions. The present invention contemplates microscale devices, comprising microdroplet transport channels, reaction regions (e.g. chambers), electrophoresis modules, and radiation detectors. In a preferred embodiment, these elements are microfabricated from silicon and glass substrates. The various components are linked (i.e., in liquid communication) using a surface-tension-gradient mechanism in which discrete droplets are differentially heated and propelled through etched channels. Electronic components are fabricated on the same substrate material, allowing sensors and controlling circuitry to be incorporated in the same device. Since all of the components are made using conventional photolithographic techniques, multi-component devices can be readily assembled into complex, integrated systems.

Brief Summary Text (18):
It is not intended that the present invention be limited by the nature of the reactions carried out in the microscale device. Reactions include, but are not limited to, chemical and biological reactions. Biological reactions include, but are not limited to sequencing, restriction enzyme digests, RFLP, nucleic acid amplification, and gel electrophoresis. It is also not intended that the invention be limited by the particular purpose for carrying out the biological reactions. In one medical diagnostic application, it may be desirable to differentiate between a heterozygotic and homozygotic target and, in the latter case, specifying which homozygote is present. Where a given genetic locus might code for allele A or allele a, the assay allows for the differentiation of an AA from an Aa from an aa pair of alleles. In another medical diagnostic application, it may be desirable to simply detect the presence or absence of specific allelic variants of pathogens in a clinical sample. For example, different species or subspecies of bacteria may have different susceptibilities to antibiotics; rapid identification of the specific species or subspecies present aids diagnosis and allows initiation of appropriate treatment.

Brief Summary Text (20):
It has been found empirically that the methods and devices of the present invention can be used with success when, prior to the conveying described above the transport channel (or channels) is treated with a hydrophilicity-enhancing compound. It is not intended that the invention be limited by exactly when the treatment takes place. Indeed, there is some flexibility because of the long-life characteristics of some enhancing compounds.

Brief Summary Text (22):
The present invention further contemplates a method for merging microdroplets comprising: (a) providing first and second liquid microdroplets, a liquid microdroplet delivering means, and a device, said device comprising: i) a housing comprised of silicon, ii) first and second microdroplet transport channels etched in said silicon and connecting to form a third transport channel containing a reaction region, iii) a microdroplet receiving means in liquid communication with said reaction region via said transport channels, and iv) microdroplet flow-directing means arrayed along said first, second and third transport channels; (b) delivering said first liquid microdroplet via said microdroplet delivering means to said first transport channel; (c) delivering said second liquid microdroplet via said microdroplet delivering means to said second transport channel; and (d) conveying said microdroplets in said transport channels to said reaction region in said third transport channel via said microdroplet flow-directing means, thereby merging said first and second microdroplets to create a merged microdroplet.

Brief Summary Text (24):
The present invention contemplates a variety of silicon-based, microdroplet transport channel-containing devices. In one embodiment, the device comprises: i) a housing comprised of silicon, ii) a microdroplet transport channel etched in said silicon, iii) a microdroplet receiving means in liquid communication with a reaction region via said transport channels, and iv) a liquid barrier disposed between said transport channels and a microdroplet flow-directing means. In one embodiment, the device is assembled in two parts. First, the channels are etched in any number of configurations. Secondly, this piece is bonded with a silicon-based chip containing the electronics. This allows for both customization (in the first piece) and standardization (in the second piece).

Brief Summary Text (27):
"Biological reactions" means reactions involving biomolecules such as enzymes (e.g., polymerases, nucleases, etc.) and nucleic acids (both RNA and DNA). Biological samples are those containing biomolecules, such proteins, lipids, nucleic acids. The sample may be from a microorganism (e.g., bacterial culture) or from an animal, including humans (e.g. blood, urine, etc.). Alternatively, the sample may have been subject to purification (e.g. extraction) or other treatment. Biological reactions require some degree of biocompatability with the device. That is to say, the reactions ideally should not be substantially inhibited by the characteristics or nature of the device components.

Drawing Description Text (3):
FIG. 2 shows a two-part approach to construction of a silicon device of the present invention.

Detailed Description Text (2):
The present invention relates to microfabrication and biological reactions in microfabricated devices, and in particular, movement and mixing of biological samples in microdroplets through microchannels. The description of the invention involves I) design of microscale devices (comprising microdroplet transport channels, reaction chambers, electrophoresis ports, and radiation detectors) using silicon and glass substrates, II) movement of discrete microdroplets using a surface-tension-gradient mechanism in which discrete microdroplets are differentially heated and propelled through etched channels, and III) mixing of biological samples for reactions.

Detailed Description Text (3):
I. Design Of MicroScale Devices

Detailed Description Text (4):
Although there are many formats, materials, and size scales for constructing integrated fluidic systems, the present invention contemplates silicon microfabricated devices as a cost-effective solution. Silicon is the material used for the construction of computing microprocessors and its fabrication technologies have developed at an unprecedented pace over the past 30 years. While this technology was initially applied to making microelectronic devices, the same techniques are currently being used for micromechanical systems.

Detailed Description Text (5):
Continuous flow liquid transport has been described using a microfluidic device developed with silicon. See J. Pfahler et al., Sensors and Actuators, A21-A23 (1990), pp. 431-434. Pumps have also been described, using external forces to create flow, based on micromachining of silicon. See H. T. G. Van Lintel et al., Sensors and Actuators 15:153-167 (1988). By contrast, the present invention employs discrete droplet transport in silicon (i.e., in contrast to continuous flow) using internal forces (i.e., in contrast to the use of external forces created by pumps).

Detailed Description Text (6):
As a mechanical building material, silicon has well-known fabrication characteristics. The economic attraction of silicon devices is that their associated micromachining technologies are, essentially, photographic reproduction techniques. In these processes, transparent templates or masks containing opaque designs are used to photodefine objects on the surface of the silicon substrate. The patterns on the templates are generated with computer-aided design programs and can delineate structures with line-widths of less than one micron. Once a template is generated, it can be used almost indefinitely to produce identical replicate structures. Consequently, even extremely complex micromachines can be reproduced in mass quantities and at low incremental unit cost--provided that all of the components are compatible with the silicon micromachining process. While other substrates, such as glass or quartz, can use photolithographic methods to construct microfabricated analysis devices, only silicon gives the added advantage of allowing a large variety of electronic components to be fabricated within the same structure.

Detailed Description Text (7):
In one embodiment, the present invention contemplates silicon micromachined components in an integrated analysis system, including the elements identified schematically in FIG. 1. In this proposed format, sample and reagent are injected into the device through entry ports (A) and they are transported as discrete droplets through channels (B) to a reaction chamber, such as a thermally controlled reactor where mixing and reactions (e.g., restriction enzyme digestion or nucleic acid amplification) occur (C). The biochemical products are then moved by the same method to an electrophoresis module (D) where migration data is collected by a detector (E) and transmitted to a recording instrument (not shown). Importantly, the fluidic and electronic components are designed to be fully compatible in function and construction with the biological reactions and reagents.

Detailed Description Text (8):
In silicon micromachining, a simple technique to form closed channels involves etching an open trough on the surface of a substrate and then bonding a second, unetched substrate over the open channel. There are a wide variety of isotropic and anisotropic etch reagents, either liquid or gaseous, that can produce channels with well-defined side walls and uniform etch depths. Since the paths of the channels are defined by the photo-process mask, the complexity of channel patterns on the device is virtually unlimited. Controlled etching can also produce sample entry holes that pass completely through the substrate, resulting in entry ports on the outside surface of the device connected to channel structures.

Detailed Description Text (15):
Droplet motion (described generally above) is contemplated as one step in a pathway. The other steps typically involve sample mixing and a controlled reaction. For example, the integral heaters arrayed along the entire surface of the channel used for droplet motion also allow for a region of a channel to be used as a thermal reaction chamber. For sample mixing prior to the reaction, a Y-channel device is contemplated (FIG. 4A). In such a device, a fist droplet containing a first sample (e.g., nucleic acid) is moved along one channel of the Y-channel device, and a second droplet containing a second sample (e.g., a restriction digest enzyme in digestion buffer) is moved along the other channel of the Y-channel device (FIGS. 4B and 4C)

Detailed Description Text (22):
The description of the preferred embodiments involves: I) microfabrication techniques for manufacture of silicon-based devices; II) channel treatment for optimum flow and reproducibility; and III) component design (particularly the electrophoresis module and the radiation detectors).

Detailed Description Text (23):
I. Microfabrication Of Silicon-Based Devices

Detailed Description Text (24):
As noted previously, silicon has well-known fabrication characteristics and associated photographic reproduction techniques. The principal modern method for fabricating semiconductor integrated circuits is the so-called planar process. The planar process relies on the unique characteristics of silicon and comprises a complex sequence of manufacturing steps involving deposition, oxidation, photolithography, diffusion and/or ion implantation, and metallization, to fabricate a "layered" integrated circuit device in a silicon substrate. See e.g., W. Miller, U.S. Pat. No. 5,091,328, hereby incorporated by reference.

Detailed Description Text (26):
Of course, the particular fabrication process and sequence used will depend on the desired characteristics of the device. Today, one can choose from among a wide variety of devices and circuits to implement a desired digital or analog logic feature.

Detailed Description Text (27):
In a preferred embodiment, channels were prepared on 500 .mu.m thick glass wafers (Dow Corning 7740) using standard aqueous-based etch procedures. The initial glass surface was cleaned and received two layers of electron beam evaporated metal (20 nm chromium followed by 50 nm gold). Photoresist Microposit 1813 (Shipley Co.) was applied 4000 rpm, 30 seconds; patterned using glass mask 1 and developed. The metal layers were etched in chromium etchant (Cr-14, Cyantek Inc.) and gold etchant (Gold Etchant TFA, Transene Co.) until the pattern was clearly visible on the glass surface. The accessible glass was then etched in a solution of hydrofluoric acid and water (1:1, v/v). Etch rates were estimated using test wafers, with the final etch typically giving channel depths of 20 to 30 .mu.m. For each wafer, the depth of the finished channel was determined using a surface profilometer. The final stripping (PRS-2000, J. T. Baker) removed both the remaining photoresist material and the overlying metal.

Detailed Description Text (29):
Initial device design by the present inventors involved single layers of silicon. However, experience showed these to be inadequate to prevent short circuiting due to (necessary) liquid microdroplets within the channels (see experiments described below). The preferred design involves a triple layer of oxides. Such a preferred device capable of moving and mixing nanoliter droplets was constructed by bonding a planar silicon substrate to channels etched in a glass cover. A series of metal heaters was inlaid on the silicon substrate as two parallel lanes merging into a single lane (a "Y"-shape) (FIG. 5A). The heating elements were formed by first coating the wafer with a 1.0 .mu.m layer of thermal silicon dioxide Next, 0.35 .mu.m deep, 5 .mu.m wide grooves were reactive-ion etched (RIE) into the silicon dioxide following the pattern set in an overlying photoresist. Aluminum was deposited (0.35 .mu.m) across the entire wafer using electron beam evaporation and the metal layer was "lifted-off" from all surfaces having intact photoresist using a stripping solution. The metal inlay process gives a relatively planar surface and provides a uniform base for deposition of a solution-impermeable barrier layer. The barrier layer is made by a sequence of three plasma-enhanced chemical vapor depositions (PECVD): 1.0 .mu.m silicon oxide (SiO.sub.x), 0.25 .mu.m silicon nitride (Si.sub.x N.sub.y), and 1.0 .mu.m silicon oxide (SiO.sub.x) (FIG. 5B). Some heating elements were also used as resistive temperature sensors.

Detailed Description Text (32):
The heating-element wafer was bonded to a glass wafer containing etched channels with the same "Y" format. An aqueous chemical etch of concentrated hydrofluoric acid was used to produce channels with defined side walls and uniform depth. The etched channels are defined by a chromium/gold mask and are 500 .mu.m wide and approximately 20 .mu.m deep (FIG. 5C). The complementary silicon heater and glass channel wafers were aligned and then bonded with adhesive to form the finished device.

Detailed Description Text (35):
Prior to performing microdroplet motion and biological reactions, the channels are preferably treated by washing with base, acid, buffer, water and a

hydrophilicity-enhancing compound, followed by a relatively high concentration solution of non-specific protein. In a preferred embodiment, the channels are washed with approximately 100 .mu.l each of the following solutions in series: 0.1N NaOH; 0.1N HCl; 10 mM Tris-HCl (pH 8.0), deionized H.sub.2 O, Rain-X Anti-Fog (a hydrophilicity-enhancing compound commercially available from Unelko Corp., Scottsdale, Ariz.), and 500 .mu.g/.mu.l bovine serum albumin (non-specific protein commercially available in restriction enzyme grade from GIBCO-BRL). The wafer was placed on a stereoscope stage (Olympus SZ1145), and the contact pads for the heating elements were connected to a regulated power supply. Heating occurred by passing approximately 30 volts through the element in short pulses and observing the movement rate of the droplets. A detectable reduction in droplet volume from evaporation was noted in each experiment, usually of less than 30%. Droplet movement was recorded with a Hamamatsu video camera on videotape.

Detailed Description Text (37):
The present invention contemplates one or more gel electrophoresis modules as a component of the microscale device. Theoretical and empirical research has indicated that reducing the thickness of the electrophoresis channel leads to improved resolution. Thinner gels dissipate heat more readily and allow higher voltages to be used, with concomitant improvements in separation. The position and width of the electrophoresis detector are also critical to the ultimate resolution of the electrophoresis system. A micromachined electronic detector, such as a photodiode, placed in the underlying silicon substrate can be less than one micron from the gel matrix and can have a width of 5 microns or less. Since the gel length required for the resolution of two migrating bands is proportional to the resolution of the detector, the incorporation of micron-width electronic detectors can reduce the total gel length required for standard genotyping by at least an order of magnitude.

Detailed Description Text (41):
A radiation detector, consisting of a 10 .mu.m wide "p-n"-type diode with a 5 .mu.m wide guard ring around the outer edge, is fashioned directly into the silicon substrate underneath the channel. In this implementation, an integral radiation detector was chosen because of (i) high sensitivity (a single decay event), (ii) small aperture dimensions, and (iii) well-know fabrication and response characteristics. On this electrophoresis system, a 1 cm long, 3 .mu.m thick gel is able to perform as separation on a 80 and a 300 base-pair fragment of DNA. It should be noted that this diode, although currently configured for high-energy beta particle detection, can also operate as a photon detector. With proper wavelength filters and light sources, detection of fluorescence emission may be accommodated with a similar device.

Detailed Description Text (42):
Radiation detectors were prepared as follows. A 200 1/2-cm, <100>, float zone, boron-doped, p-type silicon wafer was used as a substrate. Diffused layers of phosphorus (5.times.10.sup.14 cm.sup.-2) and boron (1.times.10.sup.15 cm.sup.-2) were ion-implanted onto the sample in lithographically-defined regions; thermal silicon oxide was grown (0.2 .mu.m at 900.degree. C.) over the wafer; and contact holes were etched to the diffusion layer using buffered hydrofluoric acid solution (5:1). A 3.3 .mu.m layer of Microposit 1400-37 photoresist was patterned to define the metal pads; 50 nm chromium followed by 400 nm gold was evaporated over the resist; and the metallization lifted off the regions retaining the resist. A layer of Microposit 1813 photoresist was applied across the wafer and baked for 110.degree. C. for 30 minutes to form an aqueous solution barrier. Radioactive phosphorus (.sup.32 P) decay events could be detected using a sample of labeled DNA in PCR reaction buffer placed on the photoresist layer. The detector was connected to a charge-sensitive preamplifier (EV-Products 550A), followed by a linear shaping amplifier and a standard oscilloscope.

Detailed Description Text (48):
This example describes approaches to the problem of forming a moisture barrier over electrical elements of the microscale device. Initial prototypes employed 5000 angstroms of aluminum and covered it with PECVD SiO.sub.x. Upon testing, it was determined that the liquids were penetrating this later and destroying the aluminum heating elements.

Detailed Description Text (50):

As a follow-up approach, a thinner layer (500 angstroms) of aluminum was tried. This gave 1/10th the step height of the original prototype devices. On top of this aluminum, a triple layer of SiO.sub.x, Si.sub.x N.sub.y, and SiO.sub.x was employed. Moreover, the process for making the Si.sub.x N.sub.y layer was changed to one which would give a more dense layer. This appeared to solve the problem. However, the thinner layer of aluminum created a higher resistance which was not acceptable. It was determined that one needed a way to generate thicker layers of aluminum for lower resistance, yet keep the surface relatively smooth (planar). An etch back process was used (now called "the inlay process") to accomplish the task. By etching back into a layer of SiO.sub.x depositing aluminum in the resulting cavity, then stripping the resist mask, a surface was obtained with a step height low enough to prevent cracking of the passivation layers.

Detailed Description Text (53):
This example describes approaches to enhancing droplet motion by surface treatment. In this regard, the principle of using surface tension to cause droplets to move may be applied to either hydrophilic or hydrophobic surfaces. Glass, for instance, is naturally hydrophilic with a near zero contact angle with water. Because the oxide coating of the present invention is made principally of the same material as glass, it was expected that the devices would also exhibit near zero angles. It was discovered, however, that the actual construction materials had contact angles far from zero, thus enhancing the effects of contact angle hysteresis (discussed in greater detail in Example 3). For instance, water gave a contact angle (static) of .about.42.degree. on polyamide, .about.41.degree. on SiO.sub.2 (major component of most glasses), .about.62.degree. on silicone spray. To enhance the surface effectiveness, several treatment processes for both hydrophilic and hydrophobic surfaces were tried, as described below.

Detailed Description Text (54):
To improve the hydrophilicity of a surface, several cleaning procedures were tried. It has been reported that surface contamination and/or roughness can reduce the hydrophilicity of surfaces. Therefore, a high concentration chromic acid cleaning, a high concentration sulfuric acid cleaning, a baking procedure (to 600.degree. C. for 8 hrs. to burn off contaminates), and surface coatings were tried. The acid cleaning procedures were not as effective as the baking procedure; however, neither proved to be compatible with the devices since the concentrated acids would attack the aluminum pads and the high temperature could peal the aluminum (melting pt. .about.660.degree. C.) or break the adhesive bond between the heater chip and the channel.

Detailed Description Text (78):
The present calculations suggest that a .about.35.degree. C. difference between the front and back of a droplet should be sufficient to initiate droplet motion in a system with advancing angles of 36.degree. and receding angles of 29.degree. in a 20 .mu.m high channel. Experimental testing of actual devices however, showed that the front of the droplet heats relatively quickly thus reducing the temperature difference needed for movement between the front and the back of the droplet. This effect required us to use higher voltages to obtain droplet motion. Voltages typically in the range of .about.30.degree. Volts were found to be required to obtain motion. Further experiments showed that the resulting temperature difference was .about.40.degree. C. between the front and back of the droplet thus corroborating the initial determination of the requirements.

Detailed Description Text (79):
Discrete droplet motion in a micromachined channel structure using thermal gradients is demonstrated in the videorecorded images of FIG. 4. The device consists of a series of aluminum heaters inlaid on a planar silicon dioxide substrate (similar to the structure shown in FIG. 2) and bonded by glue to a wet-etched glass channel (20 .mu.m depth, 500 .mu.m width). Liquid samples were manually loaded into the two channels on the left using a micropipette. Heating the left interface of each droplet propels it toward the intersection of the channels. At the intersection, the droplets meet and join to form a single larger droplet. Note that, since the channel cross-section is 20 .mu.m.times.500 .mu.m, the volume of each of these droplets can be calculated from their lengths and is approximately 50 nanoliters.

Detailed Description Text (80):

The heaters along the entire surface of the channel shown in FIG. 4 allow it to be used as a thermal reaction chamber in addition to a droplet-motion device. The upper droplet in the figure contains a DNA sample, while the lower contains a restriction digest enzyme (TaqI) and digestion buffer. Following sample merging, the combined droplet was maintained at 65.degree. C. for 30 minutes using the integral heaters and temperature sensors. The completed enzymatic reaction was confirmed by expressing the droplet from the right end of the channel and loading it onto a capillary gel electrophoresis system with a laser-induced fluorescence detector. The chromatogram produced by the silicon-device sample was similar to chromatograms generated from DNA digests runs in a standard polypropylene microreaction vessel (not shown).

Detailed Description Text (82):
This example describes various approaches for bonding channels to the substrate which contains circuitry for heating and temperature sensing of the device of the present invention (see discussion of two-part construction, above). First attempts involved Polyamide; regular polyamide was unsatisfactory in that it was found the two pieces would not stick together.

Detailed Description Text (86):
Hydroxide bonding and screen printing of bonding substances was also attempted. Another option was glass tape, but the high temperatures required to melt the tape appeared to be too high for the present devices.

Detailed Description Text (90):
To form a biologically compatible heating element, the present inventors began by coating a standard silicon wafer with a 0.5 .mu.m layer of silicon dioxide. Next, a 0.3 .mu.m deep, 500 .mu.m wide channel was etched into the silicon oxide and gold or aluminum was deposited (0.3 .mu.m thick). This inlay process results in a relatively planar surface (FIG. 2A) and provides a base for deposition of a water-impermeable layer. The impermeable layer is made by a sequence of three plasma enhanced vapor depositions: silicon oxide (SiO.sub.x), silicon nitride (Si.sub.x N.sub.y), and silicon oxide (SiO.sub.x). Since the materials are deposited from the vapor phase the precise stoichiometries are not known. A thin metal heater design was used for this device rather than the doped-silicon resistive heaters previously demonstrated for micromachined PCR reaction chambers, since the narrow metal inlay allows viewing of the liquid sample through a transparent underlying substrate, such as glass or quartz. Also, the use of several independent heating elements permits a small number to operate as highly accurate resistive temperature sensors, while the majority of elements are functioning as heaters.

Detailed Description Text (91):
A device fabricated with metal resistive heaters and oxide/nitride/oxide coating was tested for biological compatibility and temperature control by using PCR amplification of a known DNA template sample. The reaction was carried out on the planar device using twenty microliters of PCR reaction mix covered with mineral oil to prevent evaporation. The reaction mixture was cycled through a standard 35-cycle PCR temperature cycling regime using the integral temperature sensors linked to a programmable controller. Since the reaction volume was significantly larger than intended for the original heater design, a polypropylene ring was cemented to the heater surface to serve as a sample containment chamber. In all test cases, the presence of amplified reaction products indicated that the silicon dioxide surface and the heater design did not inhibit the reaction. Parallel amplification experiments performed on a commercial PCR thermocycler gave similar results. A series of PCR compatibility tests indicated that the reaction on the device is very sensitive to controller settings and to the final surface material in contact with the sample (not shown).

Detailed Description Text (92):
From the above it should be evident that the present invention can be adapted for high-volume projects, such as genotyping. The microdroplet transport avoids the current inefficiencies in liquid handling and mixing of reagents. Moreover, the devices are not limited by the nature of the reactions, including biological reactions.

CLAIMS:

1. A device comprising:

i) a housing comprised of silicon,

ii) a microdroplet transport channel etched in said silicon,

iii) a microdroplet receiving means in liquid communication with a reaction region via said transport channels, and

iv) a liquid barrier disposed between said transport channels and a microdroplet flow-directing means wherein said liquid barrier comprises a first silicon oxide layer, a silicon nitride layer, and a second silicon oxide layer.

2. The device of claim 1 wherein said microdroplet flow-directing means comprises a series of heating elements arrayed along said transport channels.

3. The device of claim 1 wherein said channel has been treated with a hydrophilicity-enhancing compound.